The distribution of the Red-crowned Toadlet *Pseudophryne australis* in the Nepean-Burragorang region of the Sydney Basin

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ABSTRACT

Surveys were conducted for the Red-crowned Toadlet *Pseudophryne australis* in Burragorang State Conservation Area (SCA), Nattai National Park (NP), Thirlmere Lakes NP and the Upper Nepean SCA west of Sydney, New South Wales using a variety of methods. Scattered populations of *Pseudophryne australis* were detected by the presence of tadpoles and calling males in a range of vegetation communities. These communities included escarpment grey gum forest, exposed Burragorang sandstone shrub woodland, Nattai sandstone dry shrub forest, sheltered sandstone intermediate blue gum forest and Nepean gorge moist forest. All detections were within non-perennial creeks on Hawkesbury or Mittagong sandstones or enriched soils derived from these sandstones. The number of calling frogs at sites ranged from one to about 400. Nine 250 m transects were surveyed at night for 30 min each and 0-36 adult frogs were detected during these searches. Diurnal searches were conducted for tadpoles and adult frogs by using the 'shout' method. Tadpoles were observed at five sites, three of which had calling males. Nocturnal drive searches for calling frogs were conducted involving approximately 60 km over all the reserves. At one site *P. australis* bred in habitat highly modified by human disturbance. This site was an ephemeral pond formed by sand that had been bulldozed over a creek. Although the populations were within the reservation system the habitat connection between some reserves was narrow and subject to development pressures. The results of the surveys modified control burns to exclude breeding sites and retain leaf litter.

Key words: *Pseudophryne australis*, habitat preference, Burragorang State Conservation Area, Nattai National Park, Thirlmere Lakes National Park, Upper Nepean State Conservation Area, New South Wales.

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Introduction

The Red-crowned Toadlet *Pseudophryne australis* (Gray, 1835) is listed in New South Wales (NSW) as a threatened species under Schedule 2 of the *Threatened Species Conservation (TSC) Act, 1995.* The species distribution is broadly stated as confined to a 160 km radius around the centre of Sydney (Cogger 2014). Within this area it has a localised distribution where it exists primarily in association with exposed Hawkesbury Sandstones with few populations detected on the Narrabeen Sandstone (Thumm and Mahony 1999).

Within the Sydney basin *P. australis* persists in a number of reservation areas, however populations are fragmented by transport corridors and many have been destroyed as a result of urban development (Jacobson 1963, Thumm and Mahony 1997, 1999). Thumm and Mahony (1999) recorded 47 breeding locations, of which two had been destroyed by development, 12 were threatened by housing, 10 were potentially exposed to storm water pollution and six were totally isolated with no possibility of interaction with other populations.

In view of the status of *P. australis* we conducted targeted surveys at four reserves near the south-western limit of the species. Most of the surveys were necessary to establish the existence of the species in areas where hazard reduction burns were proposed. The primary aim was to avoid impacts on the species from the controlled burns, but we also wanted to gain an understanding of the distribution (habitat corridor) and size of populations. This paper presents findings on the habitat, number of tadpoles and calling male *P. australis* in Burragorang State Conservation Area (SCA), Nattai National Park (NP), Thirlmere Lakes NP and the Upper Nepean SCA west of Sydney, NSW.

Methods

Study area

Burragorang SCA (17,500ha), Nattai NP (49,468ha), Thirlmere Lakes NP (627ha) and Upper Nepean SCA (25,237ha) are all National Park estate located on the western fringe of Sydney, New South Wales (Fig. 1). The first three areas form a contiguous block of bushland and there is a native vegetation link to the Upper Nepean SCA along the Nepean River. The first three areas are also located within the East Warragamba Catchment Area managed by Water NSW (formerly the Sydney Catchment Authority) and the Upper Nepean SCA is located within the Metropolitan Special Area.

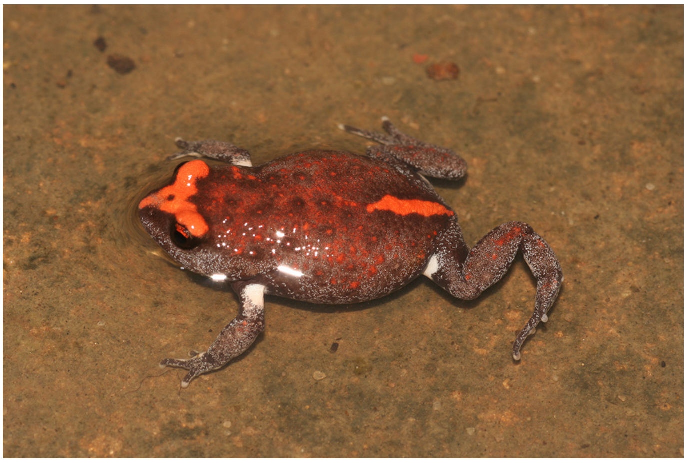

Figure 1. Red-crowned Toadlet *Pseudophryne australis.*

Site selection

With the exception of the Upper Nepean SCA the surveys were conducted to establish the distribution and abundance of *P. australis* prior to the implementation of hazard reduction burns in the study areas. Since *P. australis* occurs in the upper reaches of small drainage lines a site was usually defined by the specific drainage line, the exception was the transect surveys along Hoddles Head Rd, which involved searches upstream and downstream from a set point where the species had previously been detected (Table 1).

Survey methods

Survey sites were assessed using the criteria developed by the Office of Environment and Heritage (OEH) for amphibian surveys (DECC 2009). All survey sites were located along first order ephemeral creeks (Fig. 2). A single night survey of all sites was conducted at Thirlmere Lakes NP and Nattai NP on 8 and 10 November 2010 and Upper Nepean SCA on 7 December 2010 and 19-21 March 2013 within Burragorang SCA (Table 1). The surveys were conducted within the breeding season for *P. australis* (Anstis 2002, Lemckert and Mahony 2008). Nattai NP and the Upper Nepean SCA received intense rainfall prior to the nocturnal surveys in 2010 that stimulated *P. australis* breeding activity.

Nine 250m long search areas were sampled for 30 min each (NPWS 1997). These transects were inspected during the day prior to the nocturnal searches. At Hoddles Head Rd in Nattai NP, where *P. australis* had previously been detected (OEH atlas record), two transects were

Table 1. Site locations, date and effort for surveys.

Grid references - Eastings and northings in ADG Z56, GDA 94 datum. Eastern Standard Time used for search periods. FT = Fire trail

Site number	Reservation Area	Site Name	Alt.	Easting	Northing	Date of survey	Number of P. australis detected	Diurnal or Nocturnal Survey Period (hours)
1	Nattai NP	Sandy Flat FT	370	270807	6215869	8.xi.10	2 males	Nocturnal drive transect
2	Thirlmere Lakes NP	Thirlmere Lake	320	272567	6210120	10.xi.10	3 males	Diurnal - opportunistic
3	Nattai NP	W41 FT	300	271027	6210250	10.xi.10	5 males	Nocturnal drive transect
4	Nattai NP	W41 FT	250	267407	6213493	10.xi.10	8 males	Nocturnal drive transect
5	Nattai NP	W41 FT	250	267268	6213570	10.xi.10	1 male plus tadpoles	Nocturnal drive transect
6	Nattai NP	Hoddles Head Rd_1	405	267840	6216170	8.xi.10	12 males	18.46-19.16
7	Nattai NP	Hoddles Head Rd_2	405	267851	6216222	8.xi.10	34 males, 2 females plus tadpoles	18.46-19.16
8	Upper Nepean SCA	Avon Dam Rd	480	281901	6197225	7.xii.10	c. 400 males	Nocturnal drive transect
9	Upper Nepean SCA	Tip creek	360	280000	6199357	14.iii.12	zero	20.01 - 20.31
10	Upper Nepean SCA	Hambridge Creek	330	279734	6198941	15.iii.12	zero	18.39 - 19.09
11	Burragorang SCA	Braddocks Rd_2	280	273245	6234098	13.ii.12	11 males	21.12-21.42
12	Burragorang SCA	West Creek	250	273068	6233777	13.ii.12	1 males	22.33-23.03
13	Burragorang SCA	Braddocks Rd_1	270	273508	6234889	14.ii.12	2 males	Diurnal - opportunistic
13	Burragorang SCA	Braddocks Rd_1	270	273508	6234889	14.ii.12	2 tadpoles One male called after time	20.30-21.00
14	Burragorang SCA	Dinner Creek	400	264197	6226198	15.ii.12	zero	20.22-20.52
14	Burragorang SCA	Dinner Creek	400	264197	6226198	16.ii.12	50 tadpoles	Diurnal
15	Burragorang SCA	Rangers Creek	420	266905	6222091	19.iii.13	tadpoles	19.34-20.14

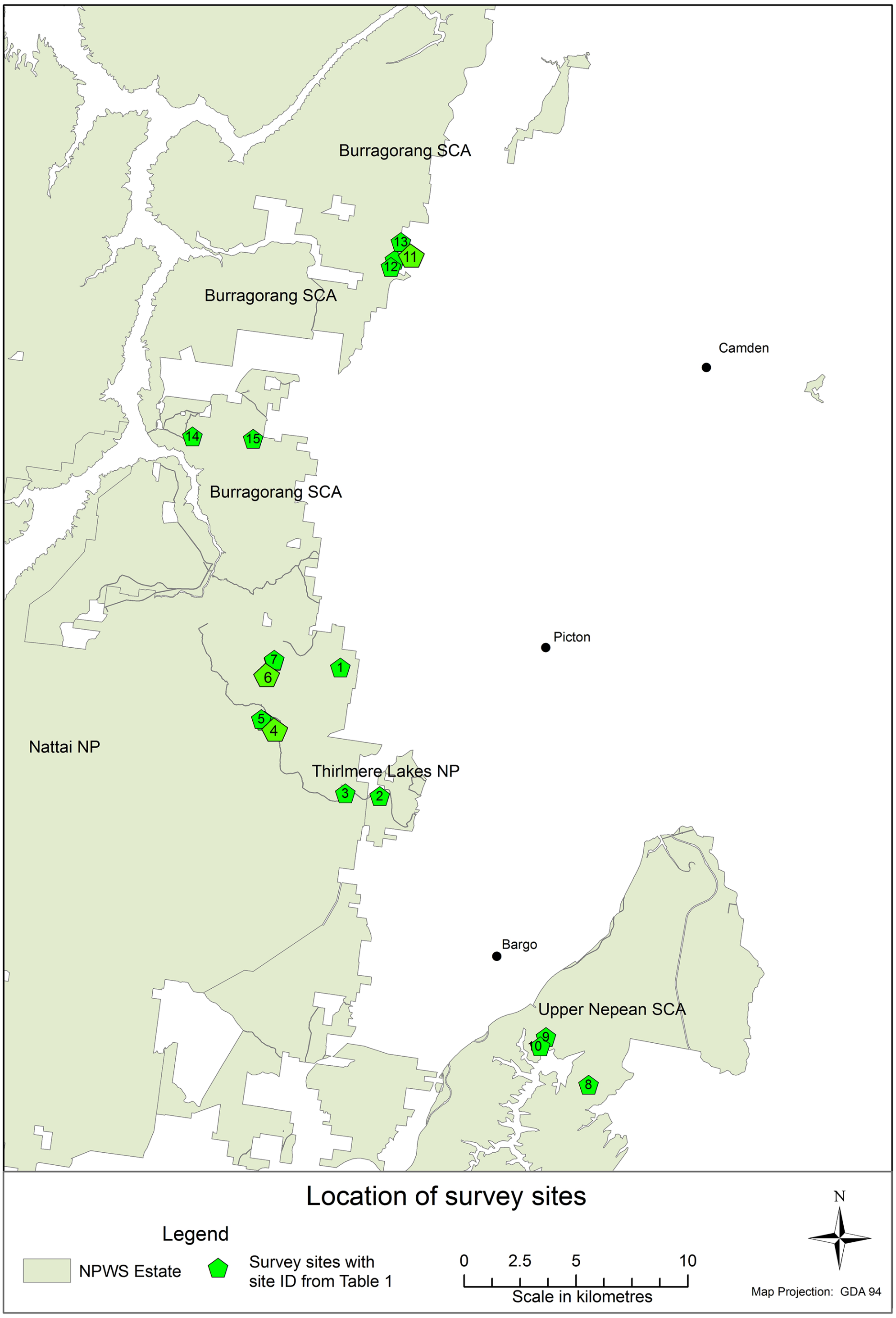

Figure 2. Survey locations for the Red-crowned Toadlet *Pseudophryne australis* in the Neapean-Burragorang region.

searched, one upstream and one downstream of the creek crossing, otherwise transects were separated by a distance of at least one kilometre (Table 1). The crossing at Hoddles Head Rd had been formed by sand being bulldozed over the creek.

Surveys for *P. australis* also included drive transects and approximately 60 km of road were driven slowly with the windows down and frogs identified by call. At some locations in Nattai NP *P. australis* potential breeding sites were flagged during diurnal searches to facilitate the location of these sites for nocturnal drive surveys. Surveys conducted during the day utilised the fact that *P. australis* can respond to humans making loud noises (in this case shouting the word hey) and this method facilitated detection of frogs. In some cases the frogs that were detected by call were found and sighted to confirm identity. Diurnal searches were conducted for *P. australis* tadpoles, the species having distinct morphology (Anstis 2002). The sites varied in altitude from 250 to 420 m AHD (Table 1) and covered a range of habitats within the reserves. A description of the tree and shrub species, edaphic qualities/parameters, disturbance history and stream characteristics was included in the survey.

Habitat

The Wollongong-Port Hacking soil landscape series sheet (DLWC) indicates that the area has soils derived from Hawkesbury and Mittagong sandstone (Hazelton *et al.* 1990). The habitat within the immediate area of the creeks varied from steep narrow races of intermittent water on exposed rounded sandstone rocks with narrow shale lenses to relatively flat areas with sandy pools (range between circa 0.05-0.2 m deep). The vegetation at the sites has been classified as Escarpment Grey Gum Forest, Exposed Burragorang Sandstone Scrub Woodland, Nattai Sandstone Dry Scrub Forest and Sheltered Sandstone Intermediate Blue Gum Forest (Nattai NP) (DEC 2003, NPWS 2003, 2004).

Escarpment Grey Gum Forest occurs on the Permian alluvial sediments from the Shoalhaven group. These sediments are predominantly sandstone but also have a mix of shale and siltstone (DEC 2004). The most abundant species is Grey Gum *Eucalyptus punctata* with depauperate Yellow Bloodwood *Corymbia eximia,* Sydney Peppermint *Eucalyptus piperita* and Forest Oak *Allocasuarina torulosa*. The shrub layer is sparse, comprising Prickly Rasp Fern *Doodia aspera,* Coffee Bush *Breynia oblongifolia,* Sticky Daisy Bush *Olearia viscidula,* Australian Indigo *Indigofera australis* and Downy Chance *Clerodendrum tomentosum*.

Exposed Burragorang Sandstone Shrub Woodland is a low open forest to woodland that occurs on Hawkesbury and Narrabeen Sandstones. The canopy is dominated by Sydney Peppermint, Red Bloodwood *Corymbia gummifera* and Yellow Bloodwood with White Stringybark *E. globoidea*. A relatively dense heath layer consists of Saw Banksia *Banksia serrata,* Broad-leaved Geebung *Persoonia levis,* Hairpin Banksia *Banksia spinulosa* var. *spinulosa,* Finger Hakea *Hakea dactyloides,* Sunshine Wattle *Acacia terminalis,* Mountain Devil *Lambertia formosa* and Paperbark Tea-tree *Leptospermum trinervium*.

Nattai Sandstone Dry Shrub Forest is found on Hawkesbury sandstone is dominated by Red Bloodwood, Sydney Peppermint and Stringybarks (*E. agglomerata, E. globoidea, E. oblonga* and *E. eugenioides*). The understorey is a diverse mix of low shrubs and heath species such as Hairpin Banksia, Broad-leaved Geebung, Paperbark Tea-tree, Flax-leaved Wattle *Acacia linifolia,* Woody Pear *Xylomelum pyriforme* and Lance Beard-heath *Leucopogon lanceolatus* var. *lanceolatus.*

Sandstone Moist Blue Gum Forest is found on enriched sandstone derived soils derived from the Permian alluvial sediments. It is characterised by tall forest (30 m), dominated by Mountain Blue Gum *Eucalyptus deanei*, Smooth-barked Apple *Angophora costata* and Turpentine *Syncarpia glomulifera* subsp. *glomulifera* with a sub-canopy of Cedar Wattle *Acacia elata,* Lillypilly *Acmena smithii* and Coachwood *Ceratopetalum apetalum* in the lower canopy. This community is dominated by ferns, including the Rough Tree Fern *Cyathea australis*, False Bracken *Calochlaena dubia,* Austral Bracken *Pteridium esculentum* and Gristle Fern *Blechnum cartilagineum.*

Nepean Gorge Moist Forest is found in deeply dissected Hawkesbury sandstone gullies. It is characterised by tall forest, dominated by River Peppermint *E. elata,* Sydney Peppermint and Stringybark *E. agglomerata.* At this site there was a small occurrence of Silvertop Ash *E. sieberi* in the upper catchment. The sub-canopy includes Cedar Wattle, Coachwood and Christmas Bush *Ceratopetalum gummiferum.* The shrublayer includes Rough Tree Fern, Blueberry Ash *Elaeocarpus reticulatus* and Native Oliver *Notelaea longifolia.* The understorey was dense and consisted of False Bracken, Austral Bracken and Gristle Fern.

Results

Pseudophryne australis was detected at six of seven sites in Burragorang SCA, all six sites within Nattai NP, the one site in Thirlmere NP and one of the three sites within the Upper Nepean SCA. The number of adult male *P. australis* detected at other sites in the Burragorang – Nattai area ranged from 1-11. The nine streamside searches detected between 0 and 36 adult frogs. Breeding activity was recorded at Nattai NP, Thirlmere Lakes NP and the Upper Nepean SRA during November and December and February in Burragorang SCA. The tadpoles found in Burragorang SCA were late Gosner (1960) stage and hence did not give a clear indication of when breeding had occurred. Five sites were found using the nocturnal drive technique with three of these sites located using the shout method. Tadpoles were found at five sites, three of which calling males were detected (Table 1). *Pseudophryne australis* was detected on sandstones derived from the Hawkesbury (Nattai and Thirlmere NP, Upper Nepean SCA) and Mittagong formation (Bargo SCA).

At Hoddles Head Rd in Nattai NP the creek had been dammed by a road being bulldozed over the drainage line. No pipes had been laid to reticulate water under the road and water pooled immediately upstream after substantial rain. One male responded to a shout and was subsequently found within leaf litter during the day. The nocturnal survey of this site conducted that night detected 36 adults (including two females) during a 30 min search. There was no free water at this site at that time. The road had been built in the 1950's and it is suggested that it had benefited *P. australis* as searches six weeks after the initial nocturnal surveys revealed tadpoles of *P. australis* (and *Litoria dentata*) at this site in a pool that measured approximately 5 x 5 x 0.15 m deep.

Twelve male *P. australis* were detected approximately 80 m downstream from the road during another streamside search that night. At this site the males were calling from the creekline near a Common Wombat *Vombatus ursinus* burrow. It was suspected that after substantial periods of rain, water would pool at the lowest point within the Wombat burrow. Searches six weeks later revealed this site was dry. Both sites had a gentle slope with deep sandy soil. Frogs were calling amongst leaf litter or seen active on the surface.

Pseudophryne australis were found within a portion of one creek, which was an eastern tributary of the Nepean River within the Upper Nepean SCA. The population size was estimated by recording the location of calling males from the upper catchment to a point downstream where the last frogs were heard calling. Based on the density of frogs heard along this transect approximately 400 males were calling. Logistics prevented searches of other nearby creeklines.

Searches on the same night on the western side of the Nepean River failed to detect *P. australis,* although *P. bibronii* was common (15 animals heard calling beside a dam and also beside the upper lateral of a creek). Hawkesbury sandstone exists on the western edge of the Nepean River, but is a relatively narrow band within the broader Mittagong shales/fine-grain sandstone (Hazelton *et al.,* 1990).

As a result of the surveys hazard reduction burns at sites that supported *P. australis* excluded the creeklines. This retained the leaf litter that was a critical component for the sites where males called and made nests.

Discussion

Status within the reserves

Apart from a section of the one creekline in the Upper Nepean SCA, *P. australis* occurred in small, scattered populations. This is probably a reflection of the habitat available for a species that has specialised breeding requirements. Only a small number of tadpoles were detected at five sites (Table 1) supporting the finding that this species has low recruitment from the tadpole stage (Thumm and Mahony 2002, Stauber 2006). The *P. australis* at the site in the pool formed from the sand being bulldozed over the creek were stationed in a smaller sub-pool where water seeped into the pond. This suggests that tadpoles have a preference for being near the incoming seepage.

During this survey a large population of *P. australis* was detected in the Upper Nepean SCA. OEH Wildlife atlas records indicate that this is the largest population recorded. Surveys for the species on that night, on western tributaries of the Nepean River failed to detect *P. australis* suggesting populations can be scattered and localised. The species has been previously detected in this conservation area but the number of animals found was comparatively small (G. Daly unpubl. data; K. Madden pers. comm.). Ehmann (1997) states that *P. australis* populations ranged between 1 and 19 individuals at 48 locations. There is a large population along Euroka Creek, a tributary of the Nepean River, in the Blue Mountains NP as 22 males were detected calling during two 30min streamside searches (G. Daly unpub. data).

Habitat at *P. australis* sites

Thumm and Mahony (1996) analysed 47 sites occupied by *P. australis* and found that the species mainly occurred on Hawkesbury sandstone with few populations occurring on Narrabeen sandstone or Wianamatta shale and only three on Quaternary sands and volcanics and one on coal measures. In the current study the species was detected on Hawkesbury sandstone, Mittagong sandstone and also on enriched sandstone soils derived from the Permian alluvial sediments.

Previous accounts of the vegetation communities in which *P. australis* occurs include: "lives in forests and woodlands, and heath" (Australian Museum website accessed 19 May 2011); open forest (OEH species profile website accessed 19 May 2011); and coastal heath, low open woodland and open forest with a xeromorphic understorey (Thumm and Mahony 1997). Webb (1983) states that the species occurs in vegetation dominated by Smooth-barked Apple, Yellow Bloodwood and Grey Gum with low scrub understorey. Daly *et al.* (2009) found *P. australis* at one site in the Dharawal reserves on the Woronora Peninsula which had a canopy of Silvertop Ash, Smooth-barked Apple and Red Bloodwood attaining 10 m in height and a shrub layer of Heath-leaved Banksia *B. ericifolia*, peas *Pultenaea* spp. and Drumsticks *Isopogon* spp.

DECC (2007) used modelling to predict the habitat of *P. australis* and concluded that the species occurs in areas of sandy, soils in upper drainage lines that supported moderately-high cover abundance of Heath-leaved Banksia. The map generated by this modelling accords with the results of the current survey and illustrates the relatively narrow habitat corridor for the species especially in the Bargo area.

Our survey results generally concur with previous studies that the species is highly associated with the upper catchments, low-fertility sandy soils, woodland and open forest with a xeromorphic understorey. The exceptions were the site in Moist Blue Gum Forest on enriched sandstone and the Nepean Gorge Moist Forest. The latter site supports the largest known population of the species.

Pseudophryne australis frequently colonises man-made table drains (Thumm and Mahony 1996). It is possible that the filling of the creek at the Hoddles Head Rd site offered an enhanced breeding habitat as water pooled for a longer period above the road than below. However, Stauber (2006) investigated *P. australis* breeding site hydroperiods and found that the duration of the maximum hydroperiods between artificial breeding sites and natural breeding sites was not significantly different. In the current situation the absence of pipes is considered the factor that facilitated water to be pooled and possibly enhance recruitment.

Previous accounts state that *P. australis* occurs from Pokolbin and Morisset in the north to Barren Grounds NP to the south and Mount Victoria in the west (Thumm and Mahony 1996). Our finding of a large population in the Upper Nepean SCA is significant as this is close to the species southern limit. One of the records of the species occurring at Barren Grounds on the OEH Wildlife atlas was attributed to the senior author. This record is erroneous and several surveys within this area (G. Daly unpub. data) have failed to detect the species. The Nepean SCA may be the southern limit of *P. australis.*

The surveys resulted in the exclusion of creekside vegetation from hazard reduction burns. This preserved the leaf litter piles and logs in the creeks, which are important habitat for refuge, calling and egg deposition for the species. High frequency fire has been listed as a Key threatened process under the *Threatened Species Conservation Act (1995)* hence the fire prescription avoided impacts. Our results illustrate the importance of conducting surveys to locate breeding habitat prior to hazard reduction burns so that these areas can be excluded from the action.

Habitat corridors between the reserves

Pseudophryne australis is stated as having low dispersal abilities (Thumm and Mahony 1999). No animals have been observed crossing sealed roads (Daly pers. obs.; Thumm pers. comm.) and many populations within the Sydney basin are in decline or have become locally extinct as a result of direct and indirect impacts of urban development (Jacobson 1963, Thumm and Mahony 1997). Although systematic monitoring over a range of sites has not been undertaken, within large conservation reserves such as Nattai NP and the upper Nepean SCA, the persistence of the species appears secure. For smaller reserves this may not be the case as the species typically has low population densities at widely scattered breeding sites.

Pseudophryne australis was strongly associated with Hawkesbury sandstone, but was also detected on sandstone from the Mittagong formation (Hazelton ***et al.*** 1990) on the Oakdale plateau near the interface with the Cumberland Plain. Within the Warragamba – Picton area these geologic units occur as surface rock to the west of the Wianamatta shales of the Cumberland Plain. The habitat corridor for *P. australis* between the Burragorang and Nepean catchments is narrow and tenuous (Fig. 1). Conservation of this habitat and the animals that use them is important for species such as *P. australis* that generally occur in small, scattered populations and have limited dispersal ability.

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